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THE OUTSTANDING PROBLEMS OF RELATIVITY[1]

IT was in January, 1914, that Einstein[2] made his great departure from the Newtonian doctrine of gravitation by abandoning the idea that the gravitational potential is scalar. The thirteen eventful years which have passed since then have seen the rapid development of the new theory, which is called general relativity, and the confirmation by astronomers and astrophysicists of its predictions regarding the bending of light rays by the sun and the displacement of spectral lines. At the same time a number of new problems have arisen in connection with it; and perhaps the time has now come to review the whole situation and to indicate where there is need for further investigation.

Speaking from this chair I may perhaps be permitted to recall that my first experience of the British Association was as one of the secretaries of Section A nearly thirty years ago; and that my secretarial duties brought me the privilege of an introduction to the distinguished mathematical physicist, Professor G. F. FitzGerald, of Dublin, who was a regular and prominent member of the section until his death in 1901. FitzGerald had long held an opinion which he expressed in 1894 in the words "Gravity is probably due to a change of structure of the ether, produced by the presence of matter."[3] Perhaps this is the best description of Einstein's theory that can be given in a single sentence in the language of the older physics: at any rate it indicates the three salient principles, firstly, that gravity is not a force acting at a distance, but an effect due to the modification of space (or, as FitzGerald would say, of the ether) in the immediate neighborhood of the body acted on; secondly, that this modification is propagated from point to point of space, being ultimately connected in a definite way with the presence of material bodies; and thirdly, that the modification is not necessarily of a scalar character. The mention of the ether would be criticized by many people to-day as something out of date and explicable only by the circumstance that FitzGerald was writing thirty-three years ago; but even this criticism will not be universal; for Wiechert and his fol-

[1] Address before Section A—Mathematical and Physical Sciences—the British Association for the Advancement of Science, Leeds, 1927.

[2] *Zeits. f. Math. u. Phys.* 63 (1914), p. 215.

[3] FitzGerald's *Scientific Writings*, p. 313.

lowers have actually combined the old ether theory with ideas resembling Einstein's by the hypothesis that gravitational potential is an expression of what we may call the specific inductive capacity and permeability of the ether, these qualities being affected by the presence of gravitating bodies. Assuming that matter is electrical in its nature, it is inferred that matter will be attracted to places of greater dielectric constant. It seems possible that something of this sort was what FitzGerald had in mind.

Let us now consider some of the consequences of Einstein's theory. One of the first of them is that when a planet moves round a central attracting body in a nearly circular orbit, the perihelion of the orbit advances by (approximately) $6\pi v^2/c_2$ in each revolution, where v is the planet's velocity and c is the velocity of light. This gives for the motion of the perihelion of Mercury almost exactly the amount (42″ per century) which is found from observation. Another consequence is that light-rays which pass near a massive body are deflected, the bending at the sun's limb being 1″·75. This was confirmed observationally by the British expeditions to the eclipse of May, 1919, and still more decisively by the Lick Observatory expedition to the Australian eclipse of September, 1922: the Lick observers found for the shift 1″·72 ± 0″·11, which differs from Einstein's predicted value by much less than its estimated probable error. Yet another result of general relativity is that, by the principle of equivalence, light which reaches us from a place of different gravitational potential (such as the sun) must exhibit a kind of Doppler effect. This "gravitational shift of the solar spectral lines" is now generally admitted to be confirmed by comparisons of wave-lengths at the center of the sun's disc with wave-lengths from the arc *in vacuo;* and in 1925 the effect was observed, on a much larger scale, by W. S. Adams in the spectrum of the companion of Sirius.

Besides the effects which have been verified observationally there are many consequences of Einstein's theory which are of interest as opening up new fields or presenting new interrelations of phenomena in astronomy and physics. For instance, there is a contribution to the precession of the equinoxes which, unlike ordinary precession, does not depend on the oblateness of the earth. Again, the bending of the rays of light near a gravitating body, which has been observed in the case of the sun and the companion of Sirius, may, theoretically at any rate, be so pronounced that the ray is permanently captured by the attracting body, and describes forever a track round and round it, which approaches spirally and asymptotically to a circle whose center is at the center of gravitation. Yet another deduction is that an electrified body, or a single electron, which is at rest in a varying gravitational field, must emit radiation. Indeed, now that a definite connection has been set up between electricity and gravitation, the whole of electromagnetic theory must be rewritten.

As a further illustration of the (as yet) unexplored possibilities of the new physics, let us consider the well-known equations for the potential of Newtonian gravitation, namely Laplace's equation

$$\frac{\delta^2 V}{\delta x^2} + \frac{\delta^2 V}{\delta y^2} + \frac{\delta^2 V}{\delta z^2} = 0$$

in space where there is no matter, and Poisson's equation

$$\frac{\delta^2 V}{\delta x^2} + \frac{\delta^2 V}{\delta y^2} + \frac{\delta^2 V}{\delta z^2} = -4\pi\varrho$$

in space where matter of density ϱ is present. In general relativity, when the field is statical, these are replaced by an equation

$$\Delta_2 V = \tfrac{1}{2} v \left(\sum_{i,k=1}^{3} a^{ik} T_{ik} + \frac{T_{00}}{N^2} \right)$$

where $\Delta_2 V$ is the Beltrami's second differential parameter for the form $ds^2 = \Sigma a_{ik}\, dx_i\, dx_k$ which specifies the line-element in the three-dimensional space, T_{ik} is the energy-tensor, and N is the velocity of light at the point. This equation reduces to Laplace's equation in one extreme case (when no matter or energy is present at the point) and to Poisson's equation in another extreme case (when the energy is entirely in the form of ordinary matter), but it offers an infinite variety of possibilities intermediate between the two, in which energy is present but not in the form of ordinary matter. It is possible that this equation, which evidently suggests an approach to the new wave-mechanics, may play as important a part in the microphysics and astrophysics of the future as the equations of Laplace and Poisson have played in the ordinary physics of the past.

Let us take another consequence of the new theory. Consider the field due to a single gravitating particle. Take any plane through the particle, and in this plane draw the family of concentric circles, whose center is at the particle. The length of the circumference of these circles will, of course, diminish as we take circles nearer to the center: and at one place we shall have a circle whose circumference is of length

$$4\pi\beta M/c^2$$

where β is the Newtonian constant of attraction, M is the mass of the particle in grams, and c is the velocity of light in empty space. When we arrive at this circle we find that the element of length directed radially towards the center is infinite: that is to say, the space within the circle is impenetrable. Every gravitating

particle has a ring-fence around it, within which no other body can approach.

It will be noticed that in all that I have said I have used the ordinary language of three-dimensional physical space, and have avoided mention of that four-dimensional world of space-time which looms so largely in most expositions of relativity. The reason is that I have been speaking only of phenomena belonging to the statical class, *i.e.*, those for which the field does not vary with the time: and for such phenomena, as Levi-Civita showed in a famous paper on the *Rendiconti dei Lincei* of 1917, the four-dimensional problem can be reduced to a three-dimensional one of the same kind as physicists have been accustomed to deal with. It may be consoling to those who distrust their own powers of doing research in four dimensions to know that in general relativity there are enough important unsolved problems of the statical type, for which capacity in three dimensions is sufficient to keep all the investigators of the world busy for at least another generation.

It is interesting to see how these new three-dimensional problems differ from those of the older physics. Taking as an example a small particle moving in a statical field in general relativity, we find that the motion is determined by Lagrangian differential equations

$$\frac{d}{dt}\left(\frac{\delta L}{\delta \dot{x}_r}\right) - \frac{\delta L}{\delta x_r} = 0 \qquad (r = 1, 2, 3)$$

just as in the classical dynamics: but L is not now a simple difference of terms of the "kinetic energy" and "potential energy" types. It shows the sound instinct of the creators of the old dynamics that they almost always studied the equations without making the assumption that L consists of terms of kinetic and potential type: and thus their discoveries remain perfectly valid in the dynamics of general relativity.

The fundamental researches of Einstein and Hilbert, with the discovery of the field equations of gravitation, were published in 1915. At that time German scientific journals did not reach this country regularly, and British physicists and mathematicians were mostly occupied in one way or another with duties arising out of the great war; so that comparatively little notice was taken of the new theory on this side of the North Sea during the first year or two of its existence, and indeed it was not until the end of the war that most of us had any opportunity of studying it. In Germany, however, it was quickly realized that general relativity was one of the most profound and far-reaching contributions that had ever been made to science. Its successful prediction of new phenomena of a most unexpected kind was an event of the first importance, but still more significant was its complete subversion of the foundations of physics and reconstruction of the whole subject on a new basis. From time immemorial the physicist and the pure mathematician had worked on a certain agreement as to the shares which they were respectively to take in the study of nature. The mathematician was to come first and analyze the properties of space and time, building up the primary science of geometry; then, when the stage had thus been prepared, the physicist was to come along with the dramatis personæ—material bodies, magnets, electric charges, light and so forth—and the play was to begin. But in Einstein's revolutionary conception, the characters created the stage as they walked about on it: geometry was no longer antecedent to physics, but indissolubly fused with it into a single discipline. The properties of space, in general relativity, depend on the material bodies that are present; Euclidean geometry is deposed from its old position of priority and from acceptance as a valid representation of space; indeed its whole spirit is declared to be alien to that of modern physics, for it attempts to set up relations between points which are at a finite distance apart, and thus is essentially an action-at-a-distance theory; and in the new world no direct relations exist at all except between elements that are contiguous to each other.

The scheme of general relativity, as put forward by Einstein in 1915, met with some criticism as regards the unsatisfactory position occupied in it by electrical phenomena. While gravitation was completely fused with metric, so that the notion of a mechanical force on ponderable bodies due to gravitation attraction was completely abolished, the notion of a mechanical force acting on electrified or magnetized bodies placed in an electric or magnetic field still persisted as in the old physics. This seemed to be an imperfection, and it was felt that sooner or later everything, including electromagnetism, would be reinterpreted and represented in some way as consequences of the pure geometry of space and time. In 1918 Weyl proposed to effect this by rebuilding geometry once more on a new foundation, which we must now examine.

Weyl fixed attention in the first place on the "light-cone," or aggregate of directions issuing from a world-point P, in which light-signals can go out from it. The light-cone separates those world-points which can be affected by happenings at P, from those points whose happenings can affect P; it, so to speak, separates past from future, and therefore lies at the basis of physics. Now the light-cone is represented by the equation $ds^2 = 0$, where ds is the element of proper time, and Weyl argued that this equation, rather than the quantity ds^2 itself, must be taken as the starting-point of the subject; in other words, it is the *ratios* of the ten coefficients g_{pq} in ds^2, and not the *actual*

values of these coefficients, which are to be taken as determined by our most fundamental physical experiences. Following up this principle, he devised a geometry more general than the Riemannian geometry which had been adopted by Einstein: instead of being specified, like the Riemannian geometry, by a single quadratic differential form

$$\sum_{p,q} g_{pq} dx_p dx_q$$

it is specified by a quadratic differential form

$$\sum_{p,q} g_{pq} dx_p dx_q$$

and a linear differential form $\sum_p \varphi_p dx_p$ together. The coefficients g_{pq} of the quadratic form can be interpreted, as in Einstein's theory, as the potentials of gravitation, while the four coefficients φ_p of the linear form can be interpreted as the scalar-potential and the three components of the vector-potential in Maxwell's electromagnetic theory. Thus Weyl succeeded in exhibiting both gravitation and electricity as effects of the metric of the world.

The enlargement of geometrical ideas thus achieved was soon followed by still wider extensions of the same character, due to Eddington, Schouten, Wirtinger and others. From the point of view of the geometer, they constituted striking and valuable advances in his subject, and they seemed to offer an attractive prospect to the physicist of combining the whole of our knowledge of the material universe into a single unified theory. The working out of the various possible alternative schemes for identifying these more general geometries with physics has been the chief occupation of relativists during the last nine years. Many ingenious proposals and adaptations have been published, and more than one author has triumphantly announced that at last the problem has been solved. But I do not think that any of the theories can be regarded as satisfactory, and within the last year or two a note of doubt has been perceptible; were we after all on the right track? At last Einstein himself[4] has made up his mind and renounced the whole movement. The present position, then, is that the years 1918–1926 have been spent chiefly in researches which, while they have contributed greatly to the progress of geometry, have been on altogether wrong lines so far as physics is concerned, and we have now to go back to the pre-1918 position and make a fresh start, with the definite conviction that the geometry of space-time is Riemannian.

Granting then this fundamental understanding, we have now to inquire into the axiomatics of the theory. This part of the subject has received less attention in our country than elsewhere, perhaps because of the more or less accidental circumstance that the most prominent and distinguished exponents of relativity in England happened to be men whose work lay in the field of physics and astronomy rather than in mathematics, and who were not specially interested in questions of logic and rigor. It is, however, evidently of the highest importance that we should know exactly what assumptions must be made in order to deduce our equations, especially since the subject is still in a rather fluid condition, and there is a possibility of effecting some substantial improvement in it by a partial reconstruction of the foundations.

What we want to do, then, is to set forth the axiomatics of general relativity in the same form as we have been accustomed to give to the axiomatics of any other kind of geometry—that is, to enunciate the primitive or undefined concepts, then the definitions, the axioms, and the existence-theorems, and lastly the deductions. In the course of the work we must prove that the axioms are compatible with each other, and that no one of them is superfluous.

The usual way of introducing relativity is to talk about measuring-rods and clocks. This is, I think, a very natural and proper way of introducing the doctrine known as "special relativity," which grew out of FitzGerald's hypothesis of the contraction of moving bodies, and was first clearly stated by Poincaré in 1904, and further developed by Einstein in 1905. But general relativity, which came ten years later, is a very different theory. In general relativity there are no such things as rigid bodies—that is, bodies for which the mutual distance of every pair of particles remains unaltered when the body moves in the gravitational field. That being so, it seems desirable to avoid everything akin to a rigid body—such, for example, as measuring-rods or clocks—when we are laying down the axioms of the subject. The axioms should obviously deal only with the simplest constituents of the universe. Now if one of my clocks or watches goes wrong, I don't venture to try and mend it myself, but take it to a professional clockmaker, and even he is not always wholly successful, which seems to me to indicate that a clock is not one of the simplest constituents of the universe. Some of the expounders of relativity have recognized the existence of this difficulty, and have tried to turn it by giving up the ordinary material clock with its elaborate mechanism, and putting forward in its place what they call an atomic clock; by which they mean a single atom in a gas, emitting light of definite frequency. Unfortunately the atom is apparently quite as complicated in its working as a material clock, perhaps more so, and is less understood; and the statement that the frequency is the same under all conditions,

[4] *Math. Ann.* 97 (1926), p. 99.

whatever is happening to the atom, is (whether true or not) a highly complex assumption which could scarcely be used in an axiomatic treatment of the subject until it has been dissected into a considerable number of elementary axioms, some of them perhaps of a disputable character.

It seems to me that we should abandon measuring-rods and accurate clocks altogether, and begin with something more primitive. Let us then take any system of reference for events—a network of points to each of which three numbers are assigned—which can serve as spatial coordinates, and a number indicating the succession of events at each point to serve as a temporal coordinate. Let us now refer to this coordinate system, the paths which are traced by infinitesimal particles moving freely in the gravitational field. Then it is one of the fundamental assumptions of the theory that these paths are the geodesics belonging to a certain quadratic differential form

$$\sum_{p,q} g_{pq} dx_p dx_q.$$

The truth or falsity of this assumption may, in theory at any rate, be tested by observation, since if the paths are geodesics they must satisfy certain purely geometrical conditions, and whether they do or not is a question to be settled by experience.

Granting for the present that the paths do satisfy these conditions, let us inquire if a knowledge of the paths or geodesics is sufficient to enable us to determine the quadratic form. The answer to this is in the negative, as may easily be seen if we consider for a moment the non-Euclidean geometry defined by a Cayley-Klein metric in three-dimensional space. In the Cayley-Klein geometry the geodesics are the straight lines of the space; but a knowledge of this fact is not sufficient to determine the metric, since the absolute may be any arbitrary quadric surface.

In order to determine the quadratic form in general relativity we must then be furnished with some information besides the knowledge of the paths of material particles. It is sufficient, as Levi-Civita has remarked, that we should be given the null geodesics, *i.e.*, the geodesics along which the quadratic form vanishes. In the Cayley-Klein geometry these are the tangents to the absolute; in general relativity they are simply the tracks of rays of light.

So from our knowledge of the paths of material particles and the tracks of rays of light we can construct the quadratic form

$$\sum_{p,q} g_{pq} dx_p dx_q$$

and then we are ready for the next great axiom, namely, Einstein's principle of covariance, that "the laws of nature must be represented by equations which are covariantive for the quadratic form

$$\sum_{p,q} g_{pq} dx_p dx_q$$

with respect to all point-transformations of coordinates."

The theory is now fairly launched and I need not describe its axiomatic development further. The point I wish specially to make is that in the above treatment there has been no mention either of length or of time: neither measuring-rod nor clock has been introduced in any way. We have left open the question whether the quadratic form does or does not represent anything which can be given directly by measuring-rods and clocks. For my own part I incline to think that the notions of length of material bodies, and time of clocks, are really rather complex notions which do not normally occur in the early chapters of axiomatic physics. The results of the ether-drift experiments of D. C. Miller at Mount Wilson in 1925, if confirmed, would seem to indicate that the geometry which is based on rigid measuring-rods is actually different from the geometry which is based on geodesics and light-rays.

The actual laws of nature are most naturally derived, it seems to me, from the Minimum Principle enunciated in 1915 by Hilbert, that "all physical happenings (gravitational, electrical, etc.) in the Universe are determined by a scalar world-function $\mathfrak{H}$ being, in fact, such as to annul the variation of the integral

$$\int\int\int\int \mathfrak{H}\, dx_0 dx_1 dx_2 dx_3."$$

This principle is the grand culmination of the movement begun 2,000 years ago by Hero of Alexandria with his discovery that reflected light meets the mirror at a point such that the total path between the source of light and the eye is the shortest possible. In the seventeenth century Hero's theorem was generalized by Fermat into his "Principle of Least Time" that "Nature always acts by the shortest course," which suffices for the solution of all problems in geometrical optics. A hundred years later this was further extended by Maupertuis, Euler and Lagrange into a general principle of "Least Action" of dynamical systems, and in 1834 Hamilton formulated his famous principle which was found to be capable of reducing all the known laws of nature—gravitational, dynamical and electrical—to a representation as minimum-problems.

Hilbert's minimum principle in general relativity is a direct application of Hamilton's principle, in which the contribution made by gravitation is the integral of the Riemann scalar curvature. Thus gravitation acts so as to make the total amount of the curvature of space-time a minimum: or as we may say, *gravitation simply represents a continual effort of the universe to straighten itself out.* This is general relativity in a single sentence.

I have already explained that the curvature of space-time at any point at any instant depends on the physical events that are taking place there: in statical systems, where we can consider space of three dimensions separately from time, the mean curvature (*i.e.*, the sum of the three principal curvatures) of the space at any point is proportional to the energy-density at the point. Since, then, the curvature of space is wholly governed by physical phenomena, the suggestion presents itself that the metric of space-time may be determined *wholly* by the masses and energy present in the universe, so that space-time can not exist at all except in so far as it is due to the existence of matter. This doctrine, which is substantially due to Mach, was adopted in 1917 by Einstein, and has led to some interesting developments. The point at issue may be illustrated by the following concrete problem: if all matter were annihilated except one particle which is to be used as a test-body, would this particle have inertia or not? The view of Mach and Einstein is that it would not; and in support of this view it may be urged that, according to the deductions of general relativity, the inertia of a body is increased when it is in the neighborhood of other large masses; it seems needless, therefore, to postulate other sources of inertia, and simplest to suppose that *all* inertia is due to the presence of other masses. When we confront this hypothesis with the facts of observation, however, it seems clear that the masses of whose existence we know—the solar systems, stars, and nebulæ—are insufficient to confer on terrestrial bodies the inertia which they actually possess; and therefore if Mach's principle were adopted, it would be necessary to postulate the existence of enormous quantities of matter in the universe which have not been detected by astronomical observation, and which are called into being simply in order to account for inertia in other bodies. This is, after all, no better than regarding some part of inertia as intrinsic.

Under the influence of Mach's doctrine, Einstein made an important modification of the field-equations of gravitation. He now objected to his original equations of 1915 on the ground that they possessed a solution even when the universe was supposed void of matter, and he added a term—the "cosmological term" as it is called—with the idea of making such a solution impossible. After a time it was found that the new term did not do what it had been intended to do, for the modified field-equations still possessed a solution—the celebrated "De Sitter World"—even when no matter was present; but the De Sitter world was found to be so excellent an addition to the theory that it was adopted permanently, and with it of course the cosmological term in the field-equations; so that this term has been retained for exactly the opposite reason to that for which it was originally introduced.

The "De Sitter World" is simply the universe as it would be if all minor irregularities were smoothed out: just as when we say that the earth is a spheroid, we mean that the earth would be a spheroid if all mountains were leveled and valleys filled up. In the case of the De Sitter universe the leveling is a more formidable operation, since we have to smooth out the earth, the sun, and all the heavenly bodies, and reduce the world to a complete uniformity. But after all, only a very small fraction of the cosmos is occupied by material bodies; and it is interesting to inquire what space-time as a whole is like when we simply ignore them.

The answer is, as we should expect, that it is a manifold of constant curvature. This means that it is isotropic (*i.e.*, the Riemann curvature is the same for all orientations at the same point), and is also homogeneous. As a matter of fact, there is a well-known theorem that any manifold which is isotropic in this sense is necessarily also homogeneous, so that the two properties are connected. A manifold of constant curvature is a projective manifold, *i.e.*, ordinary projective geometry is valid in it when we regard geodesics as straight lines; and it is possible to move about in it any system of points, discrete or continuous, rigidly, *i.e.*, so that the mutual distances are unaltered.

The simplest example of a manifold of constant curvature is the surface of a sphere in ordinary three-dimensional Euclidean space; and the easiest way of constructing a model of the De Sitter world is to take a pseudo-Euclidean manifold of five dimensions in which the line-element is specified by the equation

$$-ds^2 = dx^2 + dy^2 + dz^2 - du^2 + dv^2$$

and in this manifold to consider the four-dimensional pseudosphere whose equation is

$$x^2 + y^2 + z^2 - u^2 + v^2 = R^2.$$

The pseudospherical world thus defined has a constant Riemannian measure of curvature $-1/R^2$.

The De Sitter world may be regarded from a slightly different standpoint as having a Cayley-Klein metric, governed by an absolute whose equation in four-dimensional homogeneous coordinates is

$$x^2 + y^2 + z^2 - u^2 + v^2 = 0$$

where u is time. Hyperplanes which do not intersect the absolute are spatial, so spatial measurements are elliptic, *i.e.*, the three-dimensional world of space has the same kind of geometry as the surface of a sphere, differing from it only in being three-dimensional instead of two-dimensional. In such a geometry there is a natural unit of length, namely, the length of the complete straight line, just as on the surface of a sphere there is a natural unit of length, namely, the length of a complete great circle.

We are thus brought to the question of the dimensions of the universe: what is the length of the complete straight line, the circuit of all space? The answer must be furnished by astrophysical observations, interpreted by a proposition which belongs to the theory of De Sitter's world, namely, that the lines of the spectrum of a very distant star should be systematically displaced; the amount of displacement is proportional to the ratio of the distance of the star from the observer to the constant radius of curvature R of the universe. In attempting to obtain the value of R from this formula we meet with many difficulties: the effect is entangled with the ordinary Doppler effect due to the radial velocity of the star; it could in any case only be of appreciable magnitude with the most distant objects; and there is the most serious difference of opinion among astronomers as to what the distance of these objects really is. Within the last twelve months the distance of the spiral nebula M 33 Trianguli has been estimated by Dr. Hubble, of the Mount Wilson Observatory, at 857,000 light-years, and by Dr. Perrine, the director of the Cordoba Observatory, at only 30,000 light-years; and there is a similar uncertainty of many thousands per cent. in regard to all other very remote objects. Under these circumstances we hesitate to assign a definite length for the radius of curvature of the universe; but it is millions of light-years, though probably not greater than about a hundred millions. The curvature of space at any particular place due to the general curvature of the universe is therefore quite small compared to the curvature which may be imposed on it locally by the presence of energy. By a strong magnetic field we can produce a curvature with a radius of only 100 light-years, and of course in the presence of matter the curvature is far stronger still. So the universe is like the earth, on which the local curvature of hills and valleys is far greater than the general curvature of the terrestrial globe.

In concluding these remarks I ought perhaps to apologize for having said nothing about the relation of general relativity to the new wave-mechanics. My excuse must be that, at the request of the secretary of the British Association, this address was sent to the printer many weeks before the meeting; and the wave-mechanics is developing so rapidly that, as one eminent worker has declared, anything printed is *ipso facto* out of date.

E. T. WHITTAKER

CHARLES FULLER BAKER—A SKETCH

CHARLES FULLER BAKER, scientist, collector and pioneer, is dead—conquered on the very eve of the release which his indomitable will had long promised a harassed body. The doctors scarcely said whether it was malignant malaria or amoebic dysentery or tuberculosis to which he succumbed at last.

Five or six years ago, when I knew him as well as most men ever came to know him, Baker was living in a bamboo "bahai" on the outskirts of the dank little village of Los Baños, forty miles south of Manila.

There, in his two rooms among the tops of palm trees, with the stench of his neighbors' pigs and carabaos floating up through the cracks in his floor, he made additions to his superb collections of insects and fungi, and "thanked the Lord daily" for the ships which brought him letters from scores of unseen, unknown friends who had come to know and revere his solitary work as a scientist.

Though he was then only a little over fifty years, fever and a hundred tropic diseases had wasted his body and parched his skin, so that he looked more than seventy—very white of hair and intense of eye.

Baker lived apart from the faculty of the College of Agriculture of which he was dean. Between him and most of us was an intangible though not unfriendly something which kept him from knowing the men intimately. Perhaps he found some compensation in the pioneer conditions, which, under earlier Wisconsin skies, had stirred the blood of his father, living there among the natives, cared for only by a Japanese servant and his wife, cooling his water in a swinging earthen jar and writing his innumerable letters.

At any rate, few persons knew when intense pain made agony of his nights, or whether despair ever killed the stoic courage in his eyes. Once, when I learned he was suffering from one of his recurrent attacks, I climbed the ladder-stairs of his shack and entered the gloom of his large single room. He was lying on a narrow rattan couch, very wizened, very pale, and yet very fierce in the still, dark heat.

"Buenos Dios, senor," he greeted me gaily, without moving. I urged him to let us care for him, but it was obvious that that day at least he could not be moved.

The next noon he sent a note:

"You are placing before me a fine temptation to be sick. . . . You probably don't know that you are also tempting me to go back on one of my most cherished principles, not to give up, or to resign myself to conditions until the Angel Gabriel blows his horn."

After a week he was up once more, riding behind the gray nag along the blazing three miles of road to the college, and greeting natives and Americans alike with his sweeping, faintly mocking friendliness.

Baker virtually built the Philippine College of Agriculture. He fought for the appropriations which kept it going; he sought eagerly for a faculty fired by a kindred zeal to his own, for using the tropics as a great laboratory in which to enrich human knowledge.

A work fraught *ab initio* with disappointment! A quest implicit with futility! Baker found few men so free of ambition for personal glory, so urged by passionate scientific curiosity, that they would suffer his exile unmindful of loneliness, disease, perilous trips, neither seeking nor expecting gratitude, wealth or even academic recognition.

Next to the college he organized, to which come native lads from every part of the islands (Baker could capture their imaginations and stir their hopes as no other member of the faculty could, or bothered to do), Baker was interested chiefly in his entomological and mycological collections.

He had a surpassing knowledge of insects and fungi and he showered the laboratories of collectors in the Orient and Europe with his specimens. His own collections he gave in part to the College of Agriculture of the University of the Philippines, to the University of Hawaii and to the Smithsonian Institute in Washington, D. C.

Impressive monuments though they are to his intrepid, tireless spirit, the generations whose knowledge and whose living will be richer because of them, can scarcely glean from them a sense of the heroism of this rare and daring personality.

Yet Baker was not coldly impersonal. In strange contradiction to his own stoicism, he was generous and sympathetic with people whose difficulties were not a fraction so severe as his own.

Once he gave up a long-cherished plan for a trip to another more remote part of the islands, because a native boy who was dying of tuberculosis had neither money nor friends to care for him. Baker took the money he had put aside for the trip and sent the lad to the mountains. For his own part, he stayed in his shack and classified his treasured insects.

In his death, science has lost a worker whose invaluable contributions were all too obscured by his indifference to public recognition, and a host of scattered admirers must be reminded of his countless kindnesses.

COLIN G. WELLES

MILWAUKEE, WISCONSIN

SCIENTIFIC EVENTS

INTERNATIONAL ELECTRICAL CONGRESSES

THE Electrical Division of the Bureau of Standards has announced that it is represented at two international electrical conferences to be held in Italy this month. The International Electrotechnical Commission meeting will be attended by the Assistant Chief of the Electrical Division, Dr. J. Franklin Meyer, and Dr. J. H. Dellinger. Dr. Meyer will also attend the meeting of the International Commission on Illumination.

The sessions of the Electrotechnical Commission, the Bureau announced orally, were held at Bellagio on Lake Como from September 5 to September 13, with a special trip to Como on September 11, when the centenary of the death of Volta was commemorated in conjunction with the International Congress of Physics. After the technical sessions at Bellagio, the delegates to the meeting made a 10-day tour to various power plants and industrial establishments in Italy, ending at Rome, where a final meeting was held for formal acceptance of the results of the Commission meetings.

According to the preliminary program which has just been issued for the meeting, the Commission dealt with the standardization of electrical machinery and related problems, such as prime movers (steam engines and water turbines). During the meetings at Bellagio, consideration was given to specifications for such prime movers for switches, measuring instruments, insulating oils, lamp bases and holders, traction motors and radio electron tubes. There was also a discussion of the methods of rating the power of electrical machinery, of rating rivers in connection with water-power development, and of an international technical vocabulary covering the field of work of the Commission.

In addition to the government representatives mentioned, the sessions were attended by prominent engineers and executives, including representatives of the General Electric Company, the Westinghouse Electric & Manufacturing Company, the Edison Electric Illuminating of Boston, the New York Edison Company, the Electrical Testing Laboratories and a number of universities.

The International Commission on Illumination, which met at Bellagio from August 31 to September 3, included national committees in Great Britain, France, Italy, Germany, Belgium, Switzerland and Japan, in addition to the United States. Its work included the unification of practice in making photometric tests, the establishment of standard technical vocabularies, and in general the furtherance of good practice in lighting in the several countries.

The Bellagio meeting considered several technical problems—a primary standard of light, standard methods of comparing lights of different colors and the investigation of glare. Other matters dealing more directly with practice include proposed specifications for electric lamps, for street lighting and for the regulation of automobile headlights. There was also some general discussion of the teaching of the science and art of illumination and of the activities of lamp manufacturers in Europe and in America looking toward the improvement of illumination.

In accordance with the action taken at the last

plenary session of the commission held in Geneva in 1924, it is planned that a full session of the commission will be held in the United States next year.

THE FIELD MUSEUM PALEONTOLOGICAL EXPEDITION IN SOUTH AMERICA

PROFESSOR ELMER S. RIGGS, leader of the Second Field Museum—Captain Marshall Field Paleontological Expedition of 1926–1927 to Argentina—states in a report recently received that the expedition finished its first year's work about May 1 and returned to Buenos Aires. The itinerary of the year included seven months collecting in the Province of Catamarca and a somewhat shorter period of similar work in the Province of Buenos Aires.

The object of this expedition was to make collections of fossil mammals from the Pliocene and the Pleistocene formations of Argentina, and so to supplement the work of the First Expedition of 1923–24, which was directed toward the earlier Deseado and Santa Cruzean formations.

The expedition, like the first, was conducted under the leadership of Professor Riggs, associate curator of paleontology of the museum, and its personnel included Robert C. Thorne, of the museum staff; Dr. Rudolph Stahlecker, of Tübingen, Germany, as collector and stratigrapher, and local help employed in the regions worked.

The first base of operation was established at Andalgala, Catamarca. From there the party proceeded by pack-train across the Sierra Aconquija to the Valley of Santa Maria, in the vicinity of the pueblo San Jose. There camp was established and field operations begun in May, 1926. In this mild climate, at an altitude of 6,000 feet, it was possible to carry on the work of collecting throughout the winter months.

On the eastern side of the Valley of Santa Maria and abutting the foot of the Sierra Aconquija was encountered the series of sedimentary rock-strata which has been designated as Catamarcense and referred to the Araucanian Period (Pliocene). The entire series of clays and sandstones here exposed has a thickness of about 6,000 feet. It is highly inclined and complicated by local folding. A part of this series has been known to be fossil-bearing since 1892, when fossil mammals were discovered there by an expedition of the La Plata Museum, under the direction of Professor Adolfo Methfessel. Collections made by these gentlemen and by later Argentine collectors have been studied by Ameghino and others. They form an important part of the recorded Pliocene mammals of South America.

The better-known localities of Entre Rios, Rio Yapis and of Teopunca were gone over by the Field Museum collectors with gratifying success. Specimens of glyptodonts and of invertebrate fossils were discovered in the lowermost strata of the series. Careful sections were made of the entire formation and records kept of the faunas of the several horizons. Search for fossils was then extended over some sixty miles of these exposures in the Santa Maria Valley. Few fossils were found outside the localities explored by the Argentine collectors.

Convinced that Araucanian deposits recorded from widely separated districts of Catamarca belonged to the same period as that of the Santa Maria Valley, and acting upon apparently reliable information derived from local sources, the party pushed southward and westward into the Department of Belen. In the vicinity of Puerto Corral Quemada was found the formation Catamarcense exposed in a magnificent series, having a thickness of 7,000 feet. A fossil fauna similar to that known from the Santa Maria Valley was also recognized. This fauna was further supplemented in the upper series by more modern types of glyptodonts, armadillos and macrauchenids, which indicated a nearer approach to Pleistocene time. Among this strictly indigenous South American fauna there were recognized no immigrants of North American or European type.

At Puerto Corral Quemada a new base of operations was established. Three months of intensive collecting, with accompanying stratigraphic studies and records, brought together a wealth of fossil mammals. The collection from the two localities, while including only a few mountable skeletons, is rich in skulls and in specimens of the dermal armaments of glyptodonts and armadillos. Other groups represented by fine specimens are the typotheres, the protypotheres, the toxodonts, the macrauchenids, the gravigrade sloths, the marsupial carnivores, rodents of great variety, several large birds, a single great tortoise and a batrachian. The number totals 188 specimens, representing more than thirty known genera.

At the close of this collecting, the expedition was visited in the field by a delegation from the Argentine Museums of Buenos Aires, who leniently and courteously applied the Argentine law of embargo on the exportation of such collections.

With the approach of the rainy season in Catamarca, the party proceeded to the southern coast of the Province of Buenos Aires in quest of the great Pleistocene mammals of the pampean formations. This field, long known to be rich in fossil mammals, was found to offer but limited exposures available as collecting grounds. Moreover, the coast-line and the banks of a small number of rivers which have cut through the fertile wheat-belt of Argentina are sys-

tematically gone over year after year by collectors from the Argentine museums.

Such a field could not be expected to yield a rich collection. The Field Museum Expedition was rewarded, however, by finding some good articulated skeletons of the great ground sloths, Scelidodon, Glossotherium and Megatherium, as well as less complete specimens of the great saber-tooth tiger, Smilodon, and the South American Mastodon. All of these specimens of well-known animals were permitted to be exported to North America.

The expedition at latest reports was continuing the search for Pleistocene mammals in other fields.

THE BARTOL FOUNDATION

DR. W. F. G. SWANN returned on September 1 from a summer in England and France to take up his new work as director of the Bartol Foundation.

Eight research fellows will work in the foundation's laboratories, at 127 North 18th Street, Philadelphia, where it will be housed for the coming year, pending completion of the building now to be built for its use on the Swarthmore campus, as was announced recently by Dr. W. C. L. Eglin, president, and Dr. Howard McClenahan, secretary, of the foundation.

Dr. Swann announced the plan of inviting distinguished physicists, men of achievement in research and of international standing, to visit the foundation for a month at a time—not for the mere giving of a lecture, but to spend weeks in the laboratories, in conference with the staff regarding their investigations and regarding the unsolved problems, in general, of physics and of physical chemistry.

There are but few places in the world where research on the fundamental problems of physics, as distinguished from research regarding applications of scientific discovery, are going on under such conditions of undisturbed freedom for uninterrupted investigation as prevail at the Bartol Foundation.

Most closely akin are the Royal Institution, in London; the physical institutes at some of the great German universities, the Institute of Physics at the University of Leiden, in the Netherlands and the laboratory of Dr. Niels Bohr in Copenhagen.

The research fellows now at work at the foundation are Dr. Henry A. Barton, trained at Harvard and recently a fellow of the National Research Council; Dr. Arthur Bramley, from Princeton University; Dr. E. O. Frivold, from the University of Oslo, Norway; Dr. Thomas Hope Johnson, recently a Sterling fellow at Yale University; Dr. Wayne B. Nottingham, from Princeton University; Dr. Cassimiro del Rosario, formerly a Sterling fellow at Yale University; Dr. L. R. Maxwell, a guest at the foundation as holder of a research fellowship of the National Research Council, and Dr. Mildred Allen, who worked in physics at Yale University under Dr. Swann and now is a guest investigator. Andrew Longacre has also come from Yale University as a research assistant.

THE NEW BUREAU OF CHEMISTRY AND SOILS

DR. HENRY G. KNIGHT, dean of the college of agriculture and director of the experiment station of the University of West Virginia, has been appointed chief of the new Bureau of Chemistry and Soils of the United States Department of Agriculture by Secretary W. M. Jardine. Dr. Knight is a man of broad training in chemistry, soils and agronomy, and of extensive experience in directing research in these fields. He will assume his new duties about October 1.

The new Bureau of Chemistry and Soils which Dr. Knight is to direct combines three important research fields in the department—chemistry, soils and fixed nitrogen—formerly represented by the old Bureau of Chemistry, the Bureau of Soils and the Fixed Nitrogen Research Laboratory. The new bureau was provided for by the last Congress at the request of Secretary Jardine, and took form at the beginning of the present fiscal year on July 1.

While each of these three groups maintains its identity in the new organization, they will be associated in such a way as to facilitate the fullest cooperation and coordination of the research work. The fields covered are closely related and vitally important to agricultural development.

The research work in chemistry and chemical technology embraces fifteen divisions, taking in the research units of the old Bureau of Chemistry. This work in chemistry will be headed by Dr. C. A. Browne, who has been chief of the former Bureau of Chemistry, assisted by Dr. W. W. Skinner, who was assistant chief. Dr. Browne will also act as associate chief of the new bureau, but will, at his own request, devote his major energies to research work in chemistry.

Dr. F. G. Cottrell, who has been head of the fixed-nitrogen and fertilizer research group of divisions, continues as head of this work in the new bureau.

Dr. A. G. McCall, formerly professor in geology and soils of the University of Maryland and also formerly connected with the old Bureau of Soils of the United States Department of Agriculture, was recently appointed head of the soils work of the new Bureau of Chemistry and Soils. He was executive secretary of the First International Congress of Soil Science, which was held in Washington, D. C., in June.

Dr. Knight therefore becomes the head of an organization which has in charge of its subdivisions men of the highest standing who are recognized leaders in their special scientific fields. With highly trained specialists throughout the new bureau it promises to be a very effective agency in promoting the welfare of agriculture.

Dr. Knight was born at Bennington, Kans., July 21, 1878. He received the degree of bachelor of arts from the University of Washington in 1902, and the degree of master of arts from the same institution in 1904. He was a fellow at the University of Chicago in 1903, and received the degree of doctor of philosophy from the University of Illinois in 1907. He was assistant chemist in the University of Washington in 1903–04, professor of chemistry and state chemist of Washington 1904–1910, and director of the Washington Agricultural Experiment Station 1910–18. He served as dean of the college of agriculture and director of the experiment station of the University of Oklahoma 1918–20. He was honorary fellow at Cornell University in 1921–22. In 1922 he was appointed to the positions in West Virginia which he now resigns to accept the appointment in the Department of Agriculture.

Dr. Knight has taken active part in promoting research through the American Association of Agricultural Colleges and Experiment Stations (now the Association of Land Grant Colleges); he was a member of the executive committee of that association for several years. He is a fellow of the American Institute of Chemists, and a member of the American Chemical Society, the American Association for the Advancement of Science, Sigma Xi, Phi Beta Kappa, Alpha Zeta, Phi Kappa Phi and other societies.

SCIENTIFIC NOTES AND NEWS

THE autumn meeting of the National Academy of Sciences will be held at the University of Illinois at Urbana on October 18, 19 and 20.

CITIZENS' lectures at the Leeds meeting of the British Association were arranged as follows: Sir Oliver Lodge, "Energy"; Dr. MacGregor Skene, "By-Products of Plant Activity." Children's lectures: Mr. Kingdon Ward, "Plant Hunting on the Roof of the World"; Dr. Clarence Tierney, "Nature's Secrets."

FOUR of the delegates to the World Poultry Congress at Ottawa were honored in Quebec on August 9, when, following a luncheon in honor of the delegates, the Honorable J. E. Caron, Minister of Agriculture, presented to them the Mérite Agricole decoration of the Province of Quebec. The four delegates receiving the decoration were: P. A. Francis, of the British Agricultural Department; Professor Don Salvador Castello, director and founder of the Royal Spanish Poultry School; W. A. Kock, of Copenhagen, head of the Danish delegation to the congress, and R. W. Dunlap, assistant secretary of agriculture of the United States.

AT the close of the summer session of the Iowa State College, where he was formerly a student, Clarence D. Chamberlin, who recently made a successful flight from New York to Germany, received a certificate of distinguished service in aviation engineering.

DR. THEODOR WIEGAND, director of the State Museum in Berlin, has been elected a corresponding member by the Vienna Academy of Sciences.

DR. BÉCLERE has been elected vice-president of the Paris Academy of Medicine, in place of Dr. Balzer, who has resigned.

DR. LAURENCE H. SNYDER, associate professor of zoology at North Carolina State College, has been elected a foreign member of the Deutsche Gesellschaft für Blutgruppenforschung.

J. D. RUE, chief of the U. S. Forest Products Laboratory's pulp and paper section, will leave the laboratory about September 15 to become director of research for the Champion Fibre Company, of Canton, N. C.

AFTER spending some time in England and France, President Clarence Cook Little, of the University of Michigan, will go to the Faroe Islands to collect a species of mice to be used in his biological research. He will take part in the World Population Congress at Geneva before returning to the United States.

OWEN D. YOUNG, chairman of the board of directors of the General Electric Company, returned from Europe on August 23. While abroad Mr. Young served as chairman of the American delegation to the Stockholm meeting of the International Chamber of Commerce.

DR. WILLIAM CROCKER, director of the Boyce Thompson Institute, has left for Porto Rico. The agricultural problems in that tropical island have become so important that the establishment of a graduate school of agriculture has been provided for, whose function will be to solve these problems. The National Research Council at Washington, in charge of such projects, is to be represented by Dr. Crocker, who is chairman of the division of biology and agriculture and the natural official to act as adviser. He will study the situation, visiting the various agricultural regions, and will then help in organizing the graduate school so that it will be able to attack the problems effectively. He will probably be absent about three weeks on this mission.

DR. W. F. DRAPER, assistant surgeon-general in charge of the domestic quarantine division of the Bureau of Public Health Service, will sail for Europe on September 6 to study public health methods in Germany for two months. Dr. Draper's trip is a part of the system of international interchange of public health officials inaugurated several years ago for the purpose of keeping health officials in each country acquainted with advances in their field made by the health officials of other nations.

WITH the object of finding for the Field Museum of Natural History a suitable spot for representation in a habitat group illustrating the vegetation and landscape at the snow line of the Rocky Mountains, Dr. B. E. Dahlgren, acting curator of botany at the museum, and an assistant, Emil Sella, have left Chicago for the west. Dr. Dahlgren and Mr. Sella will be joined at Laramie, Wyoming, by Professor Aven Nelson, of the department of botany of the University of Wyoming. The party will proceed first to the Medicine Bow Mountains in Wyoming, and will explore regions at an altitude of between 10,000 and 12,000 feet. Thence they will go to Glacier National Park and elsewhere to continue their work. The proposed group is to show the alpine vegetation above the timber line in the American Rockies. Charles A. Corwin, field museum artist, will paint a background for it, showing the transition from the well-timbered zone below to the barren snow line near the top of the mountains. Actual specimens of the plant life of the region will be displayed.

DR. W. J. YOUDEN, a member of the staff of Boyce Thompson Institute, has been asked by the Forest Service of the Bureau of Plant Industry at Washington to help in planning an effective attack on the ravages of the white pine blister rust. It is a problem that involves a study of the plants that carry the disease and also of the soils. The disease has been baffling, because it occurs in scattered patches, with varying results. In some patches it is very destructive, and in other patches there is every gradation. The Government Forestry Service has spent much time in investigating it, and has accumulated a mass of data. The plan is that Dr. Youden shall study these data, determine the relative importance of the results, and work out a plan of attack. He will devote about a month to this work, visiting the different white pine regions, and finally reaching California.

DR. MEIR WANNIK, professor of agricultural chemistry in the Mikveh-Israel University of Palestine and head of the agricultural experiment station connected with that school, who came to the United States as a delegate to the International Soil Congress, recently spent some time at the Davis branch of the College of Agriculture of the University of California, studying the work being done in soil moisture by Dr. F. J. Viehmeyer, of the division of irrigation investigations.

PROFESSOR R. T. LEIPER, F.R.S., director of the division of medical zoology in the London School of Hygiene and Tropical Medicine, known for his researches into bilharziasis in Egypt, has been invited by the Egyptian Government to continue them next winter, and to advise on the best methods of combating the disease.

DR. L. KREHL has been appointed director of the Institute of Natural Therapy, which is conducted under the auspices of the government at the University of Jena. The institute is affiliated with the Kaiser Wilhelm Institute and will include the Heidelberg Institute for Cancer Research and the Heidelberg Institute for Protein Research.

DR. GEORGE ANDREWS HILL, senior astronomer of the Naval Observatory, died in Washington on August 29. He was sixty-nine years old.

HENRY DALLAS THOMPSON, since 1894 professor of mathematics at Princeton University and for forty years a member of the faculty, has died in Santa Barbara, California. Professor Thompson was sixty-three years old.

DR. WILLIAM BURNSIDE, F.R.S., late professor of mathematics at the Royal Naval College, Greenwich, died on August 21, aged seventy-five years.

PROFESSOR OTTONE BARBACCI, of the chair of pathologic anatomy at the University of Siena, has died, at the age of sixty-seven years.

THE triennial congress of the International Institute of Anthropology will be held at Amsterdam from September 19 to 24, under the presidency of Professor J. P. Kleiweg de Zwaan. It will comprise six sections: (1) physical anthropology, (2) ethnography and ethnology, (3) heredity and eugenics, (4) sociology and criminology, (5) prehistory, (6) folklore. The official languages will be French, German, English, Dutch, Spanish and Italian.

THE *Journal* of the American Medical Association states that a group of 150 physicians belonging to the Interstate Postgraduate Assembly of North America arrived recently in Paris by way of Belgium. They were received by eminent members in the medical profession, who arranged for them to visit the principal scientific centers and hospitals. A reception was held at the Elysée by the president of the republic, who accepted an honorary diploma of membership.

THE second national symposium on organic chemistry will be held at Ohio State University, December 29, 30 and 31. Suggestions for the program should be sent to the secretary of the division of organic chemistry of the American Chemical Society, Professor Frank C. Whitmore, Northwestern University, Evanston, Ill.

THE annual meeting of the American Association of Agricultural College Editors met during the last week in August at the Colorado State Agricultural College, Fort Collins.

To commemorate the forty-fifth anniversary of the opening by Thomas A. Edison of the first public electric light and power plant in the world in New York City, John W. Lieb, vice-president and general manager of the New York Edison Company, who was associated with Mr. Edison in that undertaking, on September 4 placed a wreath on a tablet which marks the site of the old plant. The ceremony was witnessed by many of the men who were associated with Edison in pioneer days of the electric industry.

CONSTRUCTION has been begun on a new building at New Orleans, La., for the tropical insect work of the Bureau of Entomology. It will contain office and laboratory quarters, a cold room controlled by a refrigeration plant, greenhouse and insectary units, and a shop for the construction of special apparatus. Storage space is provided for spray machinery and other field equipment, and two acres adjacent to the buildings are allotted for special experimental plots. The laboratory will contain a battery of incubators and other special apparatus for study under controlled conditions, and full equipment will be provided for the statistical analysis of data gathered in field experimentation where conditions are not under control. Thus factors developed by an analysis of the varying conditions in the field can be studied in parallel series under control in the laboratory.

THE North Sea Aquarium of the State Biological Institute on the Island of Helgoland has recently been opened to the public. The aquarium, with some fifty large tanks, shows the complete fauna and flora of the North Sea. The pipes that supply the tanks with sea water are of transparent celluloid, which is not subject to corrosion.

THE Minnesota Legislature at its last session reestablished the $4,000 appropriation for the Minnesota Crop Improvement Association. This fund is used chiefly in the distribution, inspection and certification of improved seeds developed at the station. The association is organized for the purpose of protecting these improved varieties and maintaining suitable stocks for seed purposes.

PROFESSOR LUIGI MANGIAGALLI has given his large private library to the Istituto Ostetrico-Ginecologico of the University of Milan, which bears his name. The library contains, in addition to 10,000 bound volumes, a large number of unbound treatises and rare complete collections of scientific reviews.

THE Establissements Dornalo, submarine specialists, will undertake in the course of the present season the taking of submarine views in the Mediterranean, in depths varying from 40 to 50 meters, with the help of a diving apparatus which will carry one man and a powerful motion picture projector. Their purpose is to take views of submarine life in its natural surroundings, by attracting to the lighted area all species usually living in these depths. These views will be used for making educational films. The work will later be extended to the tropical regions.

THE Women's Zionist Organization of America, known as Hadassah, voted recently to expend $609,000 in medical and health work in Palestine, most of which will be to support the Hadassah Medical Organization in that country. In addition to that budget, the organization voted to raise $100,000 from revenues for medical service in Palestine. The need for medical work in Palestine is considered urgent. The convention expressed its gratitude in a unanimous resolution to Nathan and Mrs. Straus, of New York, for their gift of $250,000 for a health center in Jerusalem.

UNIVERSITY AND EDUCATIONAL NOTES

TWO gifts amounting to $550,000 have been made to the medical school of the University of Chicago; $300,000 for the erection and equipment of a building to be known as the Gertrude Dunn Hicks Memorial, which shall be operated as an orthopedic hospital, and $250,000 from Mr. Louis H. Kuppenheimer to establish an endowment fund to be known as the Louis B. and Emma M. Kuppenheimer Foundation. The income is to be used for teaching and research in the department of ophthalmology.

PROFESSOR W. B. ZUKER, head of the department of chemistry of the University of Dubuque since 1921, has been appointed acting president of that institution beginning on September 1, when the resignation of Reverend K. F. Wettstone, D.D., took effect.

DR. W. L. HOWARD, director of the Davis branch of the college of agriculture of the University of California, has been appointed associate dean of the College of Agriculture to assist in the administration of the college during the temporary and partial absence of Dean E. D. Merrill.

PROFESSOR I. M. KOLTHOFF, of the University of Utrecht, has accepted a professorship of analytical chemistry at the University of Minnesota and will begin his work in October. Dr. R. S. Livingston, of the University of California, has been appointed assistant professor of physical chemistry.

DR. CARL SNEED WILLIAMSON, formerly of the Mayo Clinic, Rochester, Minn., has been appointed head of the department of surgery at the University of Arkansas School of Medicine, Little Rock, and Dr. Oliver C. Melson, also of the Mayo Clinic, has been appointed head of the department of medicine.

AFTER many years' activity as lecturer on zoology at the institute for investigations in heredity in Berlin-Dahlem, Dr. Paula Hertwig, the daughter of the former professor of biology, Oskar Hertwig, has been given the title of professor.

DISCUSSION AND CORRESPONDENCE

AGE OF THE "SATSOP" AND THE DALLES FORMATIONS OF OREGON AND WASHINGTON

GEOLOGISTS have differed regarding the ages of the "Satsop" and the Dalles formations of the Columbia River Gorge region. Because of their bearing on the history of the Gorge and for other reasons their ages are important.

During a brief investigation of these beds under the auspices of the Carnegie Institution of Washington, the writers secured fragmentary mammalian fossil remains from the Dalles formation representing not a Quaternary, but approximately an upper Miocene or lower Pliocene stage. This age determination is corroborated by the lithologic resemblance of the Dalles beds to the middle Neocene Ellensburg formation of central Washington, by the apparently similar relations of these two formations to the Columbia lavas, and by the induration of the Dalles beds, which is equal to that of lower or middle Neocene deposits of the west, but much greater than that of Quaternary formations.

In interesting papers by J H. Bretz and by I. A. Williams the "Satsop" in the Columbia River Gorge has been considered Quaternary by correlation, mainly through lithologic similarity, with the fossiliferous marine Satsop on the Washington coast. In the eastern part of the gorge, however, the writers have found the "Satsop" gravels beneath the Dalles beds. Moreover, the "Satsop" gravels can be traced into central Washington where they lie at the base of the middle Neocene Ellensburg formation. Further, the induration of the "Satsop" is considerably greater than that of other Pacific Coast upper Pliocene or Quaternary strata. For these three reasons the "Satsop" of the gorge is also believed to be approximately upper Miocene or lower Pliocene rather than Quaternary.

Since the "Satsop" of the gorge is not the correlative of the type Satsop on the coast, the new name, "Hood River Formation," is proposed for these rather unique conglomerate and sandstone strata. The type section may well be the beds so excellently exposed in the cut immediately east of the Columbia River Highway bridge across Hood River.

A more detailed statement of the evidence and of the bearing of these beds on the geological history of the region is in course of publication.

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MORE DATA

UNDER "Datum and Data" in the July 1 issue of SCIENCE, Mr. Blake says that "We speak and hence write English by ear and not by rules of grammar," and that "in ordinary use," data is not the mere plural of datum. It was, no doubt, recognition of these very unfortunate conditions that prompted the commendable letters of protest regarding the use of "data" in the singular.

There is no standard in the education of ears, and thus it becomes very difficult to eliminate "ain't" from spoken English. The old dictum that use is the law of language presupposes *good* usage, and the best existing criterion of good usage is a good dictionary. No reputable dictionary admits, or is likely to admit, "data" as a singular form.

But the correspondence which I have seen regarding the misuse of "data" entirely overlooks the chief abuse, which consists, not in using the word incorrectly as a singular, but in using it at all when the intended meaning can be more accurately expressed otherwise. Any one who cares to observe will find that, in probably nine cases out of ten, clearness can be gained by the substitution of "facts," "figures," "records," "values," "results," "information," or any one of perhaps a dozen other words which may more aptly fit the particular case. The general use of "data" for all such cases is due to the same slovenly thinking which causes a writer to use "etc." when he is at a loss for another word; or to use such expressions as "in regard to same" instead of repeating, or specifying just what he means by "same."

The laudable desire to adopt "new" words is to a considerable degree offset by failure to see that they are used accurately, and "data" is only one of a large number used erroneously more often than correctly. Though its use in the singular offends the intelligent

reader, the context usually reveals the true meaning. This seems to be less often true in the case of "strata" (used less frequently, but with at least as high a percentage of error). The same desire for new expressions fills our reading matter with such words as "résumé" (for which "summary" is usually better) and "rôle," printed (newspaper style) without accents.

Strangely enough, many a worker who conducts his investigations with the strictest accuracy of which science is capable, publishes his results with little concern for accuracy of statement or nomenclature. Unfortunately, some of the errors escape the attention of even the most vigilant editor. A flagrant error which seems to be gaining ground is the expression "different than." Only two weeks ago it occurred in the *Saturday Evening Post*—one of our most carefully edited journals.

E. H. McCLELLAND
CARNEGIE LIBRARY OF PITTSBURGH

ASSIMILATION OF FIXED NITROGEN BY HAVANA TOBACCO

EXPERIMENTS on the assimilation of different forms of combined nitrogen by Havana tobacco are being made at the Massachusetts Agricultural Experiment Station. Among results to date is the proof of ready assimilation of ureal nitrogen in the unchanged form. Plant growth, however, has not been as rapid with urea as a source of nitrogen as with sodium or calcium nitrate.

A more detailed report of the whole experiment will be made later. On account of the growing importance of urea as a commercial fertilizer, we make this progress report.

A. B. BEAUMONT
G. J. LARSINOS

STANDARD MATHEMATICAL SYMBOLS

A LIST of proposed American standard mathematical symbols has been prepared by a special committee of the American Engineering Standards Committee and the list has been submitted to the sponsor organizations. This list was noted in SCIENCE for August 12, 1927. It has been published in full in the following places: *Jour. Engin. Educ.*, June, 1927; *Jour. Soc. Auto. Engin.*, July, 1927; *Mechanical Engineering*, August, 1927. Since the American Association for the Advancement of Science is one of the sponsor organizations for this standardization project, the permanent secretary wishes to bring this matter to the attention of all members interested, with the request that they examine the list and send him their comments as soon as possible. The comments received will be placed before the executive committee of the association, which is asked officially to approve the list of proposed standard symbols.

BURTON E. LIVINGSTON,
Permanent Secretary

QUOTATIONS

A PORTRAIT PAINTER OF BIRDS

THE birds have lost their most devoted and faithful portrait painter in the tragic and untimely death of Louis Agassiz Fuertes. For he was not only a great ornithologist. He was for the birds what such an artist as Sargent was for men. There are not a few artists who have represented with more or less accuracy the color, form and pose of birds, but the portraits painted by Fuertes, who had a genius for individualizing every bird he saw even in its facial expression and in depicting what he saw with practiced vision that was as a sensitized plate, also revealed the character of the living creature. All birds of a feather look alike to the ordinary observer, but every owl and toucan painted by Fuertes, as Frank M. Chapman said in writing of him many years ago, had its individuality, was instinct with life, and differed from the drawings of the inexperienced or unsympathetic artist as a living bird from a stuffed one.

Dr. Fuertes's opportunities for field study were greater than those of any other painter of birds, from the boreal birds of the Bering Sea to the flamingoes of the warmer regions. He studied the birds of Texas, California, Nevada, Jamaica, the Gulf of St. Lawrence, the Bahamas, Florida, Saskatchewan, Alberta, Yucatan, Mexico, Colombia and Abyssinia. He made thousands of drawings, many of which have been widely reproduced and have been of the greatest value in interesting the public, children especially, in bird life, and acquainting them with the characteristics, the habits and the migrations of birds and their relation to human life.

But the contribution that will be his permanent monument in this state is his collection of portraits of the birds of New York (made for the illustration of Eaton's great work on the "Birds of New York"), which was purchased by Mrs. Russell Sage and presented to the State Museum at Albany. The birds will come and go with the seasons through the years all unwitting of his absence, but they can not become wholly extinct, for they will be preserved there as in life. He whose skill has given them this sort of immortality, in season and out, needs "no trophy, sword or hatchment o'er his bones," for they in turn will preserve the memory of his genius and of his devotion to them.—*The New York Times.*

SOME LIMITATIONS OF WARBURG'S THEORY OF THE ROLE OF IRON IN RESPIRATION

THE construction of models of biological processes has occasionally contributed greatly to the knowledge of the mechanisms of vital phenomena. However, enthusiasm over the successful construction of a model that in part duplicates the reaction of living protoplasm often obscures the fact that the duplication is only partial and misleads the investigator into undue dependence on deductive reasoning. Caution must be observed in accepting theories of the organism derived from the behavior of models, for in attempting to isolate a single process in this manner the controls and correlations that distinguish the living from the non-living are lost. Obviously, the value of any theory derived from the behavior of a model depends on the extent of resemblance between the behavior of the non-living system and the facts and characteristics of the process of the living organism which it purports to simulate.

An examination of the characteristics of biological oxidations shows that the comprehensive theory of Warburg of the mechanism of oxidations in the cell,[1] based largely upon the characteristics of his so-called models of respiration, is not free from the criticisms that have been levelled at other theories of biological processes similarly derived from models. On the contrary, the divergence between Warburg's theory and the actual facts is wide enough to justify regarding the theory as distinctly limited in application.

Briefly, Warburg has developed a theory of cellular oxidations in which iron in unknown combination with nitrogen is held to play the rôle of catalyzer. Molecular oxygen is said to enter into combination with the iron to form higher oxides of iron, and the iron-nitrogen is assigned the property of adsorbing and peculiarly loosening the bonds of amino acids in the cell. In the oxidation of carbohydrates phosphates replace nitrogen, and in the oxidation of fats the presence of the SH group is necessary. A transfer of active oxygen is thus effected, and the iron is returned to a lower oxide. Unfortunately for the theory in its present form, the facts of cellular oxidations which Warburg cites in support of his theory are in some important details disputable.

The theory demands, and Warburg has shown in the case of the unfertilized sea urchin egg,[2] that the oxygen absorption of disintegrated cells is equal to that of intact cells. This is contradictory to sound evidence[3] which shows that the chief energy-releasing oxidations in the cell are profoundly depressed by mechanical destruction of the cellular structure. This contradiction between the findings of Warburg and those of others shows that the experimental result which Warburg uses in support of his general theory is not a general but a particular case. The peculiar structure of the cell has thus been shown to be of great importance in its energetics. Warburg himself years ago[4] demonstrated the importance of the cell boundary in regulating oxidative metabolism when he showed that dilute sodium hydroxide accelerates the oxygen consumption of the sea urchin egg without entering the cell interior.

According to Warburg, anesthetics decrease oxidations in the cell because they are adsorbed by the iron-nitrogen, and are therefore described as general negative catalyzers of this reaction. However, there is abundant evidence[5] that dilute solutions of many anesthetics accelerate oxidative metabolism. The powerful action of the cyanides in depressing oxidative metabolism, Warburg asserts, strongly supports his theory. The validity of this evidence is open to question. Within certain limits the depression of oxidative metabolism in cyanide solutions increases with increasing concentration of the cyanide, but, after maximum depression characteristic of the concentration has been reached, continuous exposure does not result in further depression of oxidations. Warburg holds that the action of cyanide in depressing oxidations in protoplasm is due to its combination with iron, converting it into a form incapable of transferring oxygen. He regards the reaction between the cyanide and the iron as stoichiochemical, and he shows that the activity of an iron-nitrogen model in oxidizing an amino acid is depressed 97 per cent. by the addition of M/1000 HNC. According to this, we should expect very complete extinction of oxygen metabolism in the presence of strong cyanide. The expectation is not realized. It has been shown that M/1000 and M/2000 KNC have approximately the same effect on oxygen consumption in

[1] Warburg, O., 1921, *Biochem. Zeitschr.*, cxix, 134; 1923, *ibid.*, cxxxvi, 266; 1923, *ibid.*, cxlii, 518; SCIENCE, n. s., 1925, lxi, 575.

[2] Warburg, O., 1911, *Zeitschr. f. physiol. Chem.*, lxx, 413; 1914, *Arch. f. ges. Physiol.*, clviii, 189.

[3] Fletcher and Hopkins, 1907, *Jour. Physiol.* xxxv, 247; Harden and Maclean, 1911, *Jour. Physiol.*, xliii, 34; Batelli and Stern, 1914, *Biochem. Zeitschr.* lxvii, 443; Lund, E. J., 1921, *Amer. Jour. Physiol.*, lvii, 336. See also discussion in R. S. Lillie's book, "Protoplasmic Action and Nervous Action," Chicago, 1923, page 52, *et seq.*

[4] Warburg, O., 1910, *Zeitschr. f. physiol. Chem.*, cxvi, 305.

[5] Lillie, R. S., 1916, *Biol. Bull.*, xxx, 311 and references; Buchanan, J. W., 1923, *Jour. Exper. Zool.*, xxxviii, 331 and references.

Planaria dorotocephala, and although M/1000 KNC is lethal within a few hours, there still remains an oxygen consumption of about ten per cent. of the normal to be accounted for.[6] In Planaria agilis and in certain molluscan tissues the remaining oxygen consumption after maximum depression by cyanide is twenty per cent. of the normal.[7] Suitably diluted solutions of the cyanides appear to accelerate metabolism and in one case at least relatively strong solutions are required to depress cellular respiration.[8] It is also true that an oxidative enzyme has been isolated, the activity of which is not appreciably affected by cyanide.[9] The wide discrepancy between the theory and the observed facts is obvious. Cyanide is therefore not a "specific negative catalyst" in the strict sense that Warburg's theory requires.

A slight recovery of oxidative metabolism in the presence of cyanide has sometimes been noted. This, Warburg says, is due to the oxidation of the cyanide itself by the catalytic action of the iron-containing substance. Since the cyanide is said to render the catalyst incapable of transferring oxygen, a reasonable doubt arises that a catalyst can be instrumental in oxidizing a substance that has rendered it incapable of catalyzing an oxidative reaction.

The writer has recently studied the recovery period after depression by KNC more intimately than has been done heretofore.[10] When Planaria are removed from a solution of KNC in which their oxygen consumption has been depressed fifty per cent., the oxygen consumption rises above the normal during the first hour after removal from the cyanide. The extent of rise above normal is considerable, is independent of the duration of depression of KNC and persists, with gradual decrement, for at least six hours. To bring Warburg's theory into alignment with these facts it is necessary to assume that the quantity of active iron or of oxidizable materials in the cell increases during the period of depression. However, the fact that the extent of rise in rate of oxygen consumption above the normal is independent of the duration of depression renders these assumptions exceedingly improbable. A third assumption is possible, namely, that the catalyst, after being freed from the cyanide, becomes excessively active. Concerning this possibility there is no information available.

[6] Hyman, L. H., 1919, *Amer. Jour. Physiol.*, xlviii, 340.
[7] Allen, G. D., 1919, *Amer. Jour. Physiol.*, xlviii, 93; Gray, J., 1924, Proc. Roy. Soc., Ser. B, xcv, 95.
[8] Hyman, L. H., 1919, *Amer. Jour. Physiol.*, xlviii, 340; Townsend, 1901, Md. Agri. Exper. Sta. Bull., No. 75, 183; Lund, E. J., 1918, *Amer. Jour. Physiol.*, xiv, 365; 1921, *ibid.*, lvii, 336.
[9] Dixon and Thurlow, 1925, *Biochem. Jour.*, xix, 672.
[10] Buchanan, J. W., 1926, *Jour. Exper. Zool.*, xliv, 285.

Why anhydrous conditions are necessary for the action of the iron catalyst in commercial nitrogen-fixing processes or why the reaction is strongly inhibited by minute quantities of carbon monoxide and other impurities is unknown, despite the vast amount of research that has been expended. The oxidative reactions in the living organism go on in a much more complicated system. Warburg's emphatic postulation regarding the action of cyanide on the system may be considered premature.

From the effects of cyanides on oxidation in living systems it is perfectly clear that the resemblance between Warburg's models and the oxidative mechanisms in the cell is distinctly limited. As Warburg states, the idea that iron is of importance in oxidative metabolism is not new. Warburg's results have yielded suggestions as to the possible nature of the rôle of iron. However, the universality of iron in biological oxidative mechanisms is not proven, and his theory as at present formulated is quite inadequate to explain many of the facts that are associated with changes in rate of oxidations in the living organism.

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SPECIAL ARTICLES

VISIBLE RADIATION FROM EXCITED NERVE FIBER: THE REDDISH BLUE ARCS AND THE REDDISH BLUE GLOW OF THE RETINA

THERE is a singular phenomenon—one of the countless interesting entoptic phenomena discovered by Purkinje[1]—which has remarkable consequences. In a perfectly dark room you give yourself a band of red light—any light of the spectrum, and white light as well, will give the phenomenon but it is rather more easy to obtain with red light. What you will see is not only the band of red light, but also stretching out from it on both sides big slightly reddish blue arcs—the bigger the further away you stand. They are not of the color of the rod pigment (visual purple), which is of a slightly bluish red. The angular size and the shape of these reddish blue arcs make

[1] Purkinje: "Beobachtungen und Versuche zur Physiologie der Sinne," 1825, ii. 74. This rare work of Purkinje—so rare that Gertz reproduces the whole discussion which Purkinje gives of this phenomenon because so few of his readers will be able to see his book—has now been reproduced in Czecho-Slovakia: Purkinje, Johann Evangelista, *Opera Omnia*. Praze: C. Calve, 1919. My name for this phenomenon, "the reddish blue arcs" and "the reddish blue glow of the retina," has been very generally accepted.

it absolutely certain that what you are seeing is the fibers of the optic nerve which lie on the surface of the retina. Since the beautiful work of Vogt with blue-green (red-free) light[2] these fibers can be plainly seen in any one's eye with the aid of the ophthalmoscope; until now they had only been seen by the anatomist and by means of the entoptic phenomenon here described.

But why are these fibers visible? The explanation hitherto given, by Gertz and by others, is that the action current of the optic nerve fibers which carry the red light excitation causes a "secondary excitation" in adjoining fibers. Such a nerve current as this, however, if it occurred, would not be provided with the right "place-coefficients";[3] no adjoining fibers, though stimulated, would enable you to actually "see" the nerve fiber in question, for they would have the place-coefficients of those rods or cones from which they come. It is with nothing but rods or cones, or bipolar cells, or ganglia, that the "seeing" of these reddish blue fibers could be done.

But there is an additional feature of this phenomenon which throws great light upon its nature: it is followed by an after-image. It has been shown by Lazareff[4] directly (what was perfectly well-known before) that any production of a light sensation (whether chromatic or achromatic) due to the passage through the head of an electric current is followed by no exhaustion; the nerve is like the heart and the organs of respiration—the refractory period suffices for complete restoration. When, however, exactly the same sensation is brought about by the action of physical light upon the retina there is extreme exhaustion, as measured by the Nagel adaptometer. But what is exhaustion in the light-sensitive substance in the rods and cones? It is merely another name for the after-image.[5] The specific residual image that follows, a whitish reddish blue sensation, would be in color a less bright yellowish green. A person who gets this after-image says at once "It is a dark olive," which is correct both as regards brightness and chromatic quality. This fact excludes the possibility of any nervous structure whatever being the thing which is directly acted upon by the "blue arcs." Of this the experiment of Lazareff (*loc. cit.*) is absolute proof. His experiment is this: it is found that exactly the same visual sensation (say a slightly reddish blue) can be produced (1) by physical light and (2) by an electric current, but that in case (1) there is extreme exhaustion (and a residual image), and that in case (2) there is no exhaustion (and no residual image). What can be the cause of this extraordinary difference? The sensation (and therefore the cortical process) is the same in both cases. All the conducting nerve-fibers are certainly stimulated in both cases. But there is the possibility of a difference in what takes place in the retina:

(1) There is no question that in the case of the physical light stimulus it is the light-sensitive substance in the cones (and the rods) that is acted on, and that it is the photochemical products of the dissociation produced by light that act then on the nerve-ends in the cones and rods. If the electric current acted on the light-sensitive substance (as it is hard to think that it could—it has not got the excessive specificity of the visible radiations) then there would be no possible difference between the two situations, and there could not be (1) the existence of the residual image in the one case, and (2) its non-existence in the other. Hence we must conclude that (1) with the existence of the residual image goes the stimulation by physical light and (2) with the non-existence of the residual image goes direct stimulation of nerve by the electric current. The "blue arcs" and the "blue glow" which belong in the case of the after-images make themselves seen therefore by physical light and not by any sort of a "secondary excitation."

But this is not so strange a situation as it appears to be at first sight. There is another case in which visual sensations of all kinds are produced, but without any residual images—that in which the optic nerve is directly stimulated by pressure. There are several (no less than six) different forms in which pressure can be applied to the optic nerve:

(a) The "pressure phosphenes"—rings produced by pressure with the finger on the corner of the eye.

(b) Light-sensations (all the colors of the rainbow) produced by pressure with the hand on the whole eyeball. (This is dangerous.)

(c) What I have called the pull-phosphenes (got by moving the eyeballs vigorously to one side and the other). One sees the exit point of the optic nerve.

(d) The so-called "self-light of the retina." This is now believed to be due to permanent pressure on the retina by the fluids of the eyeball.

(e) After a fall on the ice, if one hits the back of the head, one "sees stars."

(f) In case of enucleation of the eyeball, at the

[2] Handb. der biol. Arbeitsment., 1922, Abt. V, Lief. 55, 376.

[3] It has been necessary to introduce this new term; without it we have nothing but the wholly erroneous "local sign."

[4] Lazareff, *Comptes rendues de l'Académie des Sciences*, 178, 1100, 1924.

[5] I have introduced the terms "persistent image" and "residual image" for positive after-image and negative after-image, respectively. They save the tired brain, in each case, one unnecessary syllogism.

moment when the optic nerve is cut there is a visual sensation. (J. J. Abel.)

In the last two cases, no residual image has ever been observed; in the other four cases it is perfectly well known that there is no residual image. Stimulation by the electric current then falls into the same category with stimulation by pressure—the optic nerve (or *some* part of the nervous structure—the cortex itself is sufficient—see Fedor Krause[6]) is acted on directly, while in the case of chromatic stimulation by light it is the highly specific light-sensitive substance in the cones that is acted upon photochemically.

In fact, it is any way plain that this light-sensitive substance in the cones (the *Sehstoff*[7]) has been made highly specific in order to respond *specifically* to the 160 energy-radiations in the spectrum which we can distinguish as different sensations. There is no such specificity as this in an electric current—hence one could have predicted that it could not attack the light-sensitive substance directly.

There are additional considerations:

(1) The optic nerve-fibers are non-myelenated, but occasionally there occurs a congenital defect of myelenated fibers in this region of the retina. I have had such a case and this individual did not see the blue arcs.

(2) In a case of traumatic blue-blindness, the blue arcs were seen, while there was no blue sensation from external objects. But blue blindness, even when congenital, is nearly always a retinal defect and traumatic blue-blindness is known to be due to yellowish exudations on the surface of the retina. This would prevent blue light coming through from external objects, but would not prevent the reddish blue fibers underneath it from being seen by the cones.

(3) Since it is known (a) that nerve, when excited, gives off CO_2 (Shiro Tashiro, G. H. Parker); (b) that it gives off heat which, though excessively small in amount, can be measured (A. V. Hill, *Proc. Roy. Soc.*, 1927) and (c) (more important still) that every organic substance (if of high vitality) gives off radiations which enable it to take its own photograph (A. Nodon, *Comptes rendus*, 1924, 178, 1101) it is no far cry to suppose that nerve (especially when stimulated, but perhaps also when not stimulated) can give off radiations which are *visible* by means of the human rods and cones close by.

[6] *Klin. Wochenschr.*, Jg. 3, p. 1269, 1924.

[7] This is apparently not the rod-pigment, the visual purple (as some suppose it to be), for the (white) brightness-distribution in the extreme periphery (where there are rods only) is, in photopic vision, the same as in the centre of the retina (v. Kries).

(4) But if this is the case, why has it not been discovered before, since physiologists are always working with stimulated nerve-fibers? The answer is: They do not so often work with non-myelenated fiber.[8] Moreover, they do not work in an absolutely dark room, that is necessary to seeing this phenomenon.

(5) The blue glow (seen by hardly any of the (twelve) observers who have written on this subject since Purkinje) is due to the visibility of the point-like (when seen in cross-section) bipolar cells which surround the red band.

The argument then stands thus: Nothing but the light-sensitive substance in the rods and cones can furnish an after-image, and this can be affected by nothing but physical light; consequently, when the observer sees the reddish blue arcs (and the reddish blue glow) of the retina he is actually "seeing" his own optic nerve-fibers (and bipolar cells).

I have set out my argument very fully here because, though it is really quite irrefragable, some of my readers[9] have seemed to find it difficult to follow. I have defended this view of the blue arcs and the blue glow (at Woods Hole and elsewhere) for some six or seven years. The recent work of Lazareff and Nodon, while it is delightfully to the point, is not at all essential to my proof: it has been well known since 1899 (S. I. Franz, *Psychol. Monographs;* Fedor Krause, *loc. cit.*) that visual sensations due to the electric current are not followed by an after-image[10] and so belong to a very different category from visual sensations due to physical light.[11]

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[8] Hallowell Davis, *Physiological Reviews*, 1927, p. 583. —I tried to see objectively if any light was given off by the splanchnic nerve of a dog when stimulated in a dark room by an electric current. But one would not expect a light so faint as this must be (A. V. Hill) to be seen at any distance, although it is visible to the rods and cones close by. Besides, the dog I tried was not of high vitality—it had, for several hours, been the subject of vivisections.

[9] *Proc. Nat. Acad. of Sciences, 12,* 413, 1926.

[10] Any more than sensations due to pressure.

[11] It is a singular fact—hitherto unexplained as far as I have been able to find out (but one which ought to throw great light upon the nature of the nerve impulse) —that the light-sensation produced by the electric current (galvanic) is of opposite ("complement") colors according to the direction in which the current flows, and also with the make and the break of the current [circuit?]. The colors are reddish-blue and greenish-yellow. This has led ardent followers of Hering (G. E. Müller and others) to think that our after-image is in some way involved in this—but without sufficient reason.